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LINEAR COMPRESSOR FOR AIR-CONDITIONER

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ABSTRACT

LG Electronics developed an energy efficient linear compressor for the split type heat pumps using R410A refrigerant.

The isentropic compressor efficiency of LG linear compressor for an air-conditioner at ASHRAE-T condition is more than 82%.

With the change of input voltage level, its capacity can be modulated to get better system efficiency.

The developed linear compressor shows the little energy efficiency variation with the capacity modulation.

INTRODUCTION

Based on the success of linear compressor for a refrigerator, LG electronics started to develop an energy efficient Linear Compressor for an air-conditioner. Because the load of air-conditioner is much higher than that of refrigerator and the required capacity modulation range is much wider, several key technologies to overcome in the linear compressor developments for an air-conditioner as follows are required;

1. The development of compact and highly efficient linear motor
2. The advanced technologies to reduce the acoustic noise and vibrations.
3. The electronic controller to adjust the appropriate piston stroke accurately.
4. The technologies to extend capacity modulation range widely.

DEVELOPMENTS

Overview

Figure 1 shows the configuration of the developed linear compressor for an air-conditioner. In order to make linear oscillating motion of piston, the moving magnet type linear motor was used. By using the moving magnet type linear oscillating motor, it was possible to get minimum side load due to motor with cost effective ways. Several helical compression coil springs were used to make the resonance system and to reduce the side forces due to springs. For the direct replacement of the conventional compressors, total structure was designed as the vertical type. Also the low-pressure vessel type was adapted for linear compressor.

In order to lubricate the sliding parts and to cool down the heat generated during compression process, the oil pumping system was devised. It provides sufficient oil to the piston bearing.

The vibration isolation of whole body from vessel by using suspension springs reduces the vibration of shell and the connected pipe sufficiently.



Figure 1. The structure of the developed linear compressor for an air-conditioner

Linear Motor

Figure 2 shows the configuration of linear motor. Stator is divided into outer and inner core by the moving magnets embedded in a rigid frame. A ring-shaped coil is installed inside the outer core.

To achieve minimum motor loss, the lamination of the linear motor is arranged in radial direction and the coil is wound in ring shape as shown in Figure 3. The efficiency of the developed linear motor is over 92% at the rated load condition.

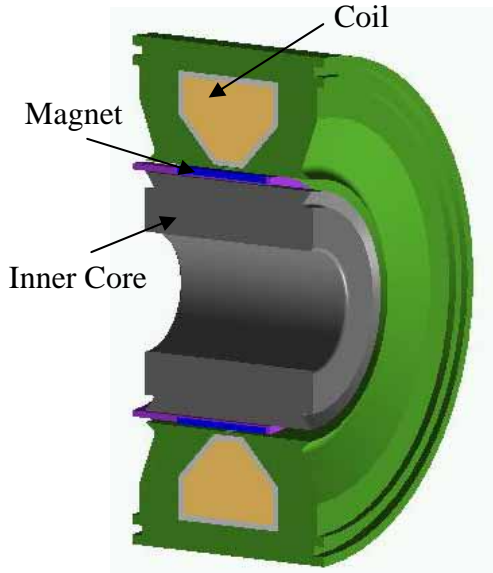


Figure 2. Schematic Diagram of Linear Motor

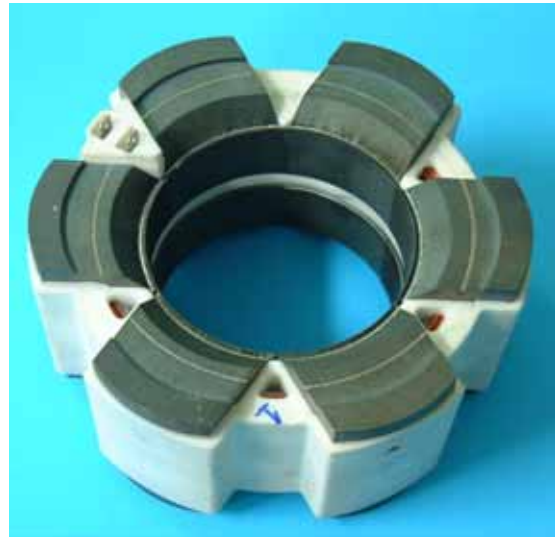


Figure 3. Outer Core

Springs

Helical compression coil spring has been selected for the resonant spring because it is cost effective and compact. Since the load of air-conditioner is several times higher than that of refrigerator, the required vertical stiffness is very higher. Basically, The side load due to spring compression is proportional to the required vertical stiffness. In order to reduce the side load due to increase of stiffness, several springs in the linear compressor for an air conditioner are selected as shown in Figure 4.



Figure 4. Resonance Spring Assembly

Valve System

To guarantee the reliability of small amount of the over-stroke of the piston, disk type discharge valve suspended by spring was designed as shown in Figure 5. This valve minimizes over-compression loss since it has bigger flow area than reed valves. Suction valve and suction flow path is placed on the piston to minimize flow resistance and heating loss of suction gas.

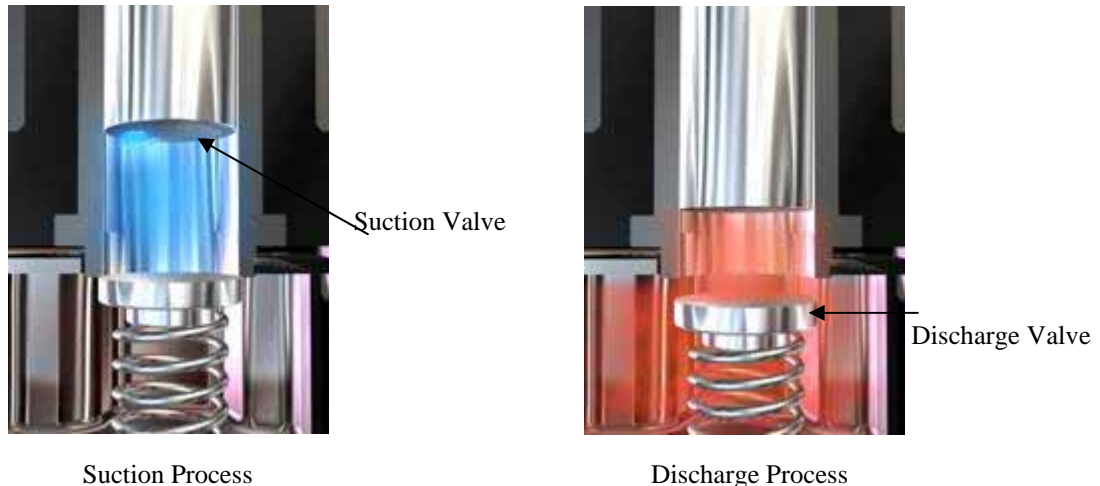


Figure 5. Suction and Discharge Process

Electronic Controller

An inverter controller (variable frequency variable voltage controller) was selected for the modulation of piston stroke in the developed linear compressor. With monitoring the piston motion by using the sensor-less stroke estimation algorithm, it changes the voltage supplied to the motor. Also, it controls the excitation frequency for maximizing the linear motor efficiency by using system resonance follow-up algorithm. In the developed linear compressor, the frequency variation range is about 5Hz. Also the accurate control of swept volume by the developed inverter drive helps to increase the reliability of piston movement, and to modulate to get better system efficiency.

PERFORMANCE

Compressor Efficiency

The developed linear motor has achieved efficiencies in excess of 92%.

Without using the crank mechanism, there is no journal bearing, crank bearing and connecting rod in linear compressor. Due to the simple mechanism, friction losses are much less than those of the conventional compressors. The mechanical efficiency of the developed linear compressor is more than 95% in the rated load condition. Additionally, tribological reliability has been improved a lot in comparison with conventional one. The valve systems of linear compressor can minimize the flow resistance, over-compression loss, and suction gas heating. It helps the improvement of the compression efficiency

Leakage loss in the linear compressor is negligible, since its compression mechanism is composed of piston and cylinder which is especially suitable for minimizing leakage.

With caring all above mentioned, the LG linear compressor achieved the extreme high efficiency. The energy efficiency ratio of LG linear compressor at ASHRAE-T condition with R410A refrigerant is more than 12.5 [BTU/H/W] (3.66[W/W]), which corresponds to 82.5% of the isentropic maximum energy efficiency ratio.

Capacity Modulation

The capacity modulation of the linear compressor can be achieved by the control of piston swept volume. Figure 6 shows the characteristics of capacity modulation of the developed linear compressor for an air-conditioner. As shown in figure, the capacity modulation range at ASHRAE-T condition is 1000~6000W cooling capacity. In the rated cooling capacity, 3500W at ASHRAE-T condition, it shows the maximal energy efficiency ratio, 12.5[BTU/H/W].

There is small EER decrease in the small cooling capacity region due to the decrease of mechanical efficiency. Comparing with the conventional compressors, the capacity modulation properties in the small capacity region are very excellent, since the leakage loss is negligible.

The 10~100% swept volume can be modulated in the developed linear compressor. It is enough to cover not only the maximum heating capacity at extreme cold weather but also energy-efficient small capacity for autumn and spring season.

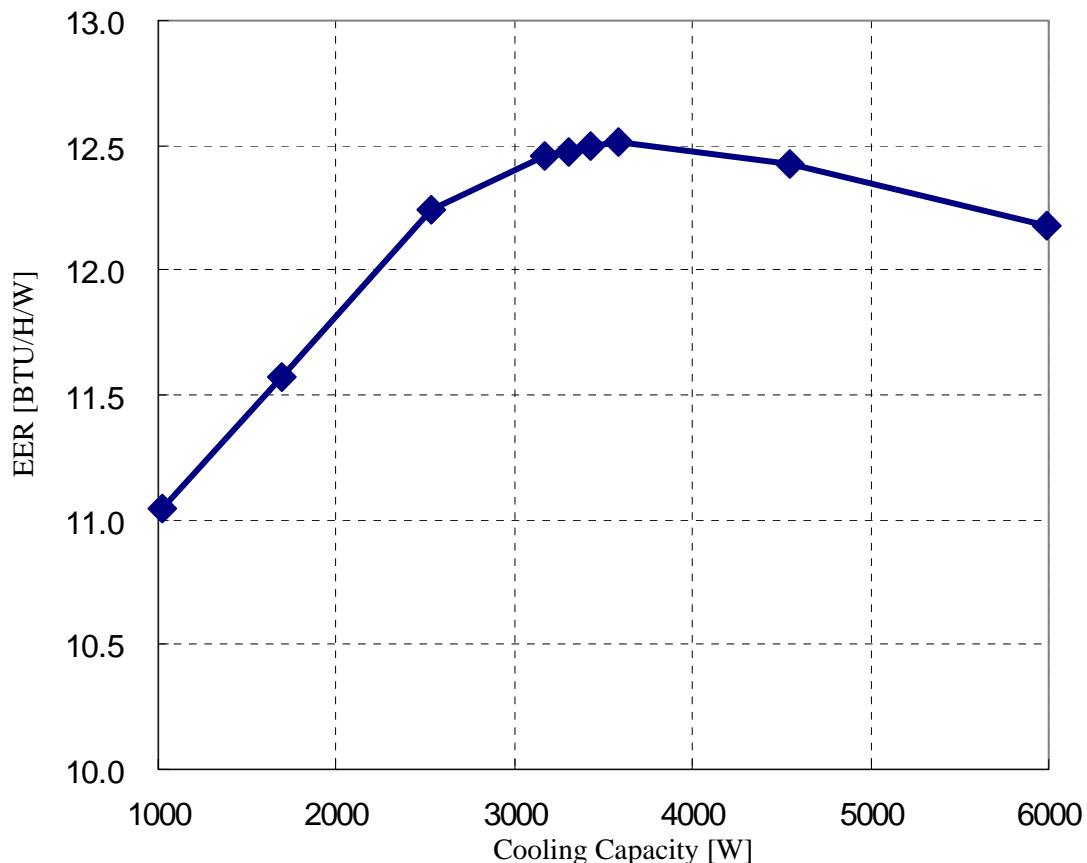


Figure 6. The Energy efficiency ratio of developed linear compressor @ ASHRAE-T, R410A refrigerant

Acoustic Noise and Vibration

The acoustic noise characteristics are basically the same as conventional reciprocating compressors.

Figure 7 shows the sound power level of linear compressor at ASHRAE-T condition. Due to impact noise of suction valve and discharge valve, the 2.5 kHz and 3.15 kHz band noise is dominant. The total sound power level is about 67dBA.

Since whole body is isolated by suspension spring, the vibration level at ASHRAE-T condition is small, under $20\mu\text{m}$.

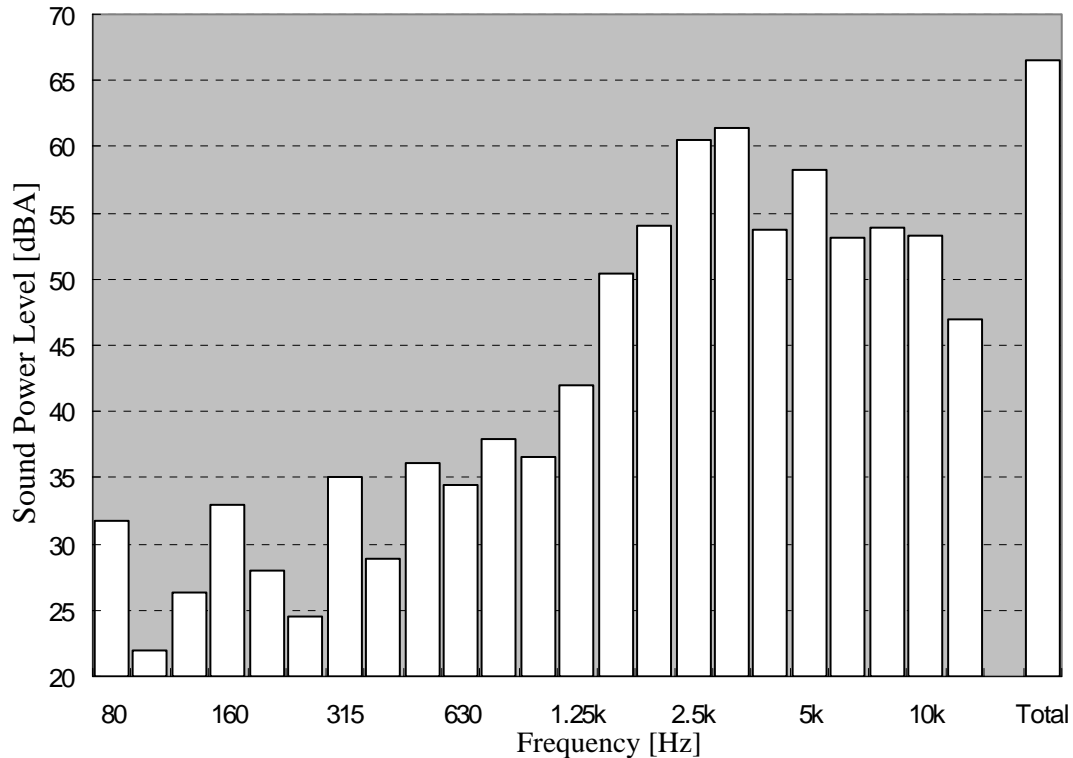


Figure 7. Sound Power Level @ ASHRAE-T, R410A refrigerant

Compressor Size and Weight

Because the outer diameter of linear motor is larger than rotating motors and the mechanical body is isolated from the shell, the compressor shell size is bigger than rotary and scroll compressor. The size of developed linear compressor is diameter 147mm and height 300mm, and its weight is about 14 kg.

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